ARMY RESEARCH LABORATORY

The Effect of Stereoscopic and Wide Field of View Conditions on Teleoperator Performance

David R. Scribner
James W. Gombash

ARL-TR-1598

MARCH 1998

Approved for public release; distribution is unlimited.

Sun™ is a trademark of Sun Microsystems, Inc.

Titmus® is a registered trademark of Titmus Optical, Inc.

Trinitron® is a registered trademark of Sony Corporation.

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5425

ARL-TR-1598 March 1998

The Effect of Stereoscopic and Wide Field of View Conditions on Teleoperator Performance

David R. Scribner
James W. Gombash
Human Research & Engineering Directorate

Abstract

A study was performed to examine the effects of stereovision and wide field of view (FOV) and their possible interaction with teleoperator performance. The study used a 2x2 (narrow versus wide FOV and mono versus stereo vision) randomized between-subjects design. There were 24 subjects in all, 6 per cell, in conditions of monoscopic-narrow FOV, monoscopic-wide FOV, stereoscopic-narrow FOV, and stereoscopic-wide FOV. No significant interaction effects were found for time or error rate measures. However, analyses of variance (ANOVAs) yielded significant differences between mono and stereo vision for error rate (number of obstacles contacted) as well as reported motion sickness symptoms on the FOV dimension. Self-reported stress levels from pre- to post-run also yielded significant differences on the mono-stereo dimension. Chi-square analyses were performed on questionnaire data for condition preferences. A first chi-square analysis revealed significant findings of first choice of viewing condition, which was stereoscopic-wide FOV. Additionally, a second chi-square analysis of unique viewing conditions showed a significant effect of stereovision; it was the single most preferred viewing condition of all four.

ACKNOWLEDGMENTS

The authors would like to thank the people who contributed their time and effort to make this study possible, especially Steve Legowics of the National Institute of Standards and Technology, for writing crucial data collection software and for debugging system control software on the high mobility, multipurpose, wheeled vehicle (HMMWV); Mr. Christopher Stachowiak for dispatching a number of day-to-day operational problems in the communication and control systems of the HMMWV; Mr. Paul Supik, Ms. Patricia Burcham, and Mr. William DeBellis for their tireless field observation and data collection efforts.

CONTENTS

TABLES

THE EFFECT OF STEREOSCOPIC AND WIDE FIELD OF VIEW CONDITIONS ON TELEOPERATOR PERFORMANCE

INTRODUCTION

The U.S. Army Research Laboratory (ARL) is the Army's lead laboratory for teleoperated vehicle systems research. The Telepresence Interface Research Team of the Soldier Systems Control Branch of the Human Research and Engineering Directorate (HRED) of ARL has a high mobility, multipurpose, wheeled vehicle (HMMWV) remotely driven via a data link and sensors that allow various configurations of visual, auditory, and simulated force feedback (see Figure 1). With the recent addition of multiple stereoscopic (stereo) camera sets, the performance benefits of wider fields of view (FOV) and stereo vision are promising but are unsubstantiated.

Figure 1. Teleoperated HMMWV with stereo cameras mounted.

The Joint Project Office Program Manager Unmanned Ground Vehicles/Systems (JPO PMUGV/S) is planning to field the first unmanned system after the year 2000 for use in reconnaissance, surveillance and target acquisition (RSTA) missions, as well as in infantry and artillery support missions. However, performance shortcomings exist for teleoperated systems. The performance shortcoming of land teleoperated systems was first identified during the Office of the Secretary of Defense (OSD) Demonstration (DEMO) I. During this demonstration of teleoperated systems technology, it was noted that to maintain proper vehicle control, vehicle operators seldom exceeded 5 mph on secondary roads. Additionally, the surrogate teleoperated vehicle (STV) operational test forced the use of two operators working simultaneously, one for vehicle operation and one for navigation. The STV system had little or no usable situational awareness information and was often lost. The fiber-optic connection to the vehicle had to be followed to find the vehicle. In addition, the STV tipped over more than once, which was attributed to a lack of vehicle orientation cues (pitch and roll and depth perception). Performance time for teleoperated driving, at present, is about twice that of on-board driving (Mitchell, Yeager, Suarez, Griffin, & Seibert, 1994). Time to complete a teleoperated driving task required approximately 6 minutes as compared to 3 minutes on board. This is most likely because vestibular input (motion sensation) was absent, the nature of the electronic viewing equipment (low resolution, FOV, and depth perception) was degraded, or both.

To address this shortcoming, the JPO PMUGV/S requested ARL's assistance in assessing the effect of new technologies on teleoperator performance. In response, ARL (HRED) developed a program to enhance the soldier performance of such systems through the exploitation of sensory feedback technologies. The goals of ARL's research program were to (a) develop a teleoperated system test bed, (b) develop a test course to benchmark system performance, (c) examine and develop metrics of system effectiveness, (d) maximize soldier performance in this environment, approaching or even exceeding on-board driving performance, and (e) identify characteristics leading to the selection of good teleoperator candidates (including resistance to simulator and motion sickness).

As stated previously, ARL is presently using a HMMWV modified for teleoperation performance studies. This includes a control station placed in a modeled section of a HMMWV. This control station (operator control unit [OCU]) is configured to provide ARL experimenters with vehicle performance data (speed, revolutions per minute, gear changes) and soldier performance data (test course completion time, error rate, steering wheel activity, brake and accelerator use). This OCU also allows the manipulation of sensory feedback variables such as monoscopic (mono) versus stereoscopic (stereo) viewing, narrow and wide FOV (55° and 165°, horizontal), monaural or binaural audio feedback, and variable steering wheel force feedback (see Figure 2). The two visual variables in question for this study are narrow and wide FOV, stereoscopic (3D) and monoscopic (2D) viewing, and their interaction.

Figure 2. ARL mock-up of the OCU.

The stereo vision system uses one ultra-high frequency (UHF) television signal that is switched at a high rate from the right to the left cameras. This signal is multiplexed between the right and left sides and brought back to the operator station via a radio link and split again to reproduce the right and left camera views simultaneously on the viewing screen. However, to receive the full stereo effect, the operator must look through a pair of electronically shuttered glasses which, in effect, synchronize the right and left eye images. The wide FOV is accomplished by using three stereo pairs of cameras to comprise a horizontal FOV just exceeding 165°. This expanded FOV is viewed on three display monitors, set next to each other, forming a semicircle.

The literature has much to say about the stereo viewing issue. Research can be traced as far back as Wheatstone (1838), who demonstrated that all that is necessary for visually perceiving objects in three-dimensional space are the two 2D retinal images and the visual motor adjustments those objects would normally produce. Most of the literature is focused into two distinct areas: remote operation of vehicles and remote operation of manipulator systems. Manipulator research is addressed first.

The common element among stereo viewing research for tele-manipulation is the performance of a task in 3D space and the associated perception of that space. Teleoperated driving can be included in this domain. Therefore, it is relevant to include performance research that concerns tele-manipulation because of its stated relevance to teleoperated driving.

Manipulation Tasks - Stereo

Several remote manipulator studies imply that there is no advantage for stereo. Kama and DuMars (1964) compared performance of a manipulator task (peg in hole) with both 2D and 3D viewing systems. They reported no advantage for stereoscopic (3D) over monoscopic (2D) viewing. However, this study was replicated by Chubb (1964) who found that the lack of significant difference in operator performance was attributable to a shortcoming in the quality of the stereoscopic viewing system. The study performed by Chubb revealed that performance times were 20% longer with the use of a 2D system instead of a 3D system, demonstrating the advantage of stereoscopic displays. In a study (Mohr, 1986) comparing high definition (HD) color TV, HD monochrome TV, standard resolution monochrome TV, and standard resolution stereo monochrome TV, the HDTV led to a lower rate of errors when remote handling tasks were performed, but the amount of time required to perform tasks was not reduced. No differences were found for the stereo condition.

In a study by Hudson and Cupit (1968), the accuracy of size and distance judgments using monocular and stereo TV displays was examined. They studied 20- to 200-foot and 4- to 12-inch inter-camera distances. Their results showed that for trained subjects, there was no significant difference between stereo and non-stereo presentations. They also maintained that there is "little superiority of 3D viewing over 2D viewing at distances of more than a few feet. This seems true for all interocular distances that have been investigated."

A study by Crooks, Freedman, and Coan (1975) reported advantages for stereo in remote manipulation tasks, specifically, reduction of positioning error. Positioning error was found to be best reduced by using a two-view system. However, stereo provided greater time reduction and reduced positioning error significantly over monoscopic conditions.

Merritt (1978) found significant advantage of stereoscopic over monoscopic displays for the peg-in-hole task, messenger line feeding task, and total error rate under three different levels of turbidity (the amount of suspended particles in water, creating varying visibility). Stereoscopic display systems were not as susceptible to turbidity differences as monoscopic display systems were.

Studies performed by Smith, Cole, Merritt, and Pepper (1979) measured subject performance in a remote manipulator peg-in-hole task under both stereo and mono TV. Task performance was superior in stereo over mono during all conditions tested. Another experiment was conducted with naïve subjects to assess the degree of learning during test conditions. Results demonstrated that the task showed significantly less advantage for stereo. This was in accordance with the authors' hypotheses. Still another experiment was conducted using visually complex tasks. Stereo was superior to mono during all conditions tested.

In 1988, Cole and Parker studied the effects of stereoscopic versus monoscopic displays on the remote performance of a simulated space station assembly task. Performance with stereo was significantly superior to that with mono in three of four experiments. The non-significance in one experiment was attributed to the accumulation of practice effects across the first two studies.

In 1989, Drascic, Milgram, and Grodski evaluated the learning effects in tele-manipulation with monoscopic versus stereoscopic remote viewing. Performance during monoscopic viewing conditions improved by 20% to 30% because of practice effects, while stereo yielded better performance throughout. Because of the richness of monoscopic depth cues, subjects were rapidly able to improve performance to nearly that of the stereoscopic display. Subjects did not demonstrate any improvement while using the stereoscopic display; they essentially performed as well during the beginning trials as the ending trials.

In another study by Drascic (1991), he demonstrated that the benefits of stereoscopic viewing, even after much practice, will still be apparent for difficult, stereoscopic vision-dependent tasks. The performance benefits of stereoscopic vision, even though they fade for highly repeatable tasks, will be strongly evident in single-attempt situations, which is often the case in a military setting.

McLean and Prescott (1991) found that manipulator performance time and failure rates for three different visual systems yielded results consistent with other stereo research, as shown in Table 1.

Table 1

Manipulator Performance Time and Failure Rates
for Three Different Visual Systems

Viewing condition	Time (s)	Failure rate (percent)
Mono	95.9	20.0
Stereo	61.3	7.0
Direct view	42.4	5.5

Driving Tasks

The available research data about teleoperated driving are extremely limited and contradictory in nature; some research proposes that there is an advantage in performance for stereo vision systems, while other research maintains that there is no advantage for stereo vision systems. No conclusive data exist that demonstrate performance or preference for monoscopic versus stereoscopic vision systems for *tactical* teleoperated driving. Tactical driving refers to driving cross country without the set of cues found in road following, where road edges provide the dominant indicator for immediate path negotiation.

Driving Tasks - Stereo

Several pieces of literature report that there are no significant differences for stereo vision specifically for driving tasks. Spain (1987) used stereoscopic versus monoscopic displays to directly drive a vehicle and found no difference between the two types of displays. Results of the advanced ground vehicle technology (AGVT) concept evaluation program (CEP) tests at Fort Knox (Kress & Almaula, 1988) showed that stereoscopic vision provided no apparent enhancement of teleoperated vehicle control. However, experience with the AGVT indicated that stereo vision may contribute to short range viewing to provide the operator better judgment of slope and extent of negative terrain features such as holes or ditches.

There are also some accounts of the advantage for stereo driving in the literature. A study performed by Pepper (1983) concluded that while stereo TV is more costly and complex, it provides performance advantages in tasks that (a) require positioning in the depth plane, and (b) involve unfamiliar scenes or reduced contrast. McGovern (1987) reports that negative obstacles are extremely difficult to see using [monoscopic] television and that this contributes to the many problems in vehicle teleoperation such as unwanted obstacle contact, vehicle positioning errors, and potential vehicle losses. McGovern suggests that stereo vision may help in the identification of negative obstacles, but no studies are reported.

Driving - Field of View

The documented evidence of the effects of varying fields of view is small but fairly consistent. Literature with direct application of data from formal studies is limited, but several sources report anecdotal evidence. The strongest data point for the utility of expanded FOV comes from studies involving driving tasks, specifically obstacle avoidance and path following.

In a reference by Kress and Almaula (1988), operators concluded that the wide FOV (three 60° FOV cameras) was very useful for turning and maneuvering in close quarters and for driving cross country. Kress and Almaula (1988) reported that wider FOVs are also useful for maintaining spatial orientation with respect to landmarks and terrain features. They also reported the width of the FOV is related to motion sickness effects and that a wide FOV would produce such effects. They also reported that wide FOV resulted in "easier operation".

McGovern (1987) also reported that drivers found it difficult to operate a vehicle in restricted space with a narrow FOV. McGovern's study used two fields of view: narrow (40° horizontal) and wide (three 40° cameras for a 120° FOV). The wider FOV resulted in "easier" operation by subjects, for critical off-road driving tasks in unfamiliar terrain. Eveleth (1976) concluded that teleoperators become preoccupied with driving tasks and are therefore unable to detect target arrays at extremely close distances. This was most likely because of the amount of concentration given to driving tasks during a narrow FOV condition.

Silverman (1982) found that there was a significant decrease in the number of obstacles hit during wide FOV as compared to narrow FOV conditions.

To the contrary, Gordon (1966) found that if a path is familiar and has no obstacles, then a narrow FOV is adequate. Gordon found that operators could drive as fast as 25 kph on a curved two-lane road with a monocular field as small as 4°. He concluded that information derived from the road edges and center line was sufficient for vehicle steering control. These cues are not available in off-road conditions.

The studies involving the use of stereo by Smith et al. (1979), Cole and Parker (1988), Drascic et al. (1989), Drascic (1991), and McLean and Prescott (1991) demonstrate an accelerated learning effect for a mono viewing condition after having trained during a stereo viewing condition in static environments. This gives credence to the opposing studies (Hudson & Cupit, 1968) that suggest no advantage for stereo viewing in trained subjects. The notion that one may learn in stereo and transfer learning to a mono viewing condition for static environments (e.g., a nuclear fuel-handling facility) is well established; however, the cost of a mistake may drastically outweigh the cost of a stereo viewing system.

The studies of McGovern (1987), Silverman (1982), and Kress and Almaula (1988) agree on the fact that a wide FOV, such as 120° to 180° horizontal, will enhance performance for teleoperators performing off-road terrain navigational tasks in unfamiliar environments.

Additionally, the simulator sickness effects of wide FOV are noted in the Kress and Almaula study as significant to the teleoperator in his or her environment.

For the application of a military field repair manipulator or a teleoperated vehicle performing a reconnaissance mission, the stereo advantage for *unfamiliar environment* is crucial. For Army teleoperation missions in which a large percentage of the missions may be conducted in off-road, unfamiliar terrain, wide FOV may prove to be a necessity for situational awareness, navigation, and close quarters maneuvering.

Hypotheses

The research on stereoscopic vision systems for teleoperation ranges from manipulation to some limited driving studies. From the data available, it is difficult to draw definite conclusions about the performance effect for monoscopic versus stereoscopic vision systems. However, depth cues provided by stereoscopic imagery are expected to have an effect on both performance and preference data over monoscopic imagery during tactical driving conditions (Chubb, 1964; Crooks et al., 1975; Merritt, 1978; Smith et al., 1979; Cole & Parker, 1988; Drascic et al., 1989; Drascic, 1991; McLean & Prescott, 1991; Pepper, 1983; McGovern, 1987). Further, it is expected that the stereoscopic vision system will yield performance advantages and will be preferred over the monoscopic vision system.

FOV is expected to yield performance and preference advantages because of the research findings and suppositions in the literature (McGovern, 1987; Eveleth, 1976; Silverman, 1982; Gordon, 1966). FOV is also expected to show a difference in reported motion sickness effects, as reported in previous documentation.

An interaction between FOV and stereopsis is expected to provide significant improvement in performance and preference over either of the individual effects.

It is also expected that the main and interaction effects of this study will yield significant changes in perceived workload, stress, and motion sickness levels.

No hypotheses or expectations were made about the control measures of steering wheel, brake, and accelerator activity.

It is important to note that all data reported in this report include actual on-board data for baseline comparison.

OBJECTIVES

The primary objective of this study is to determine if any performance, stress, cognitive workload, motion sickness, or preference differences exist between the experimental conditions of narrow and wide FOV (one center view or an expanded view with three cameras), FOV and monoscopic or stereoscopic viewing, and the interaction of the two feedback mechanisms under a tactical driving task.

METHODS

Participants

Participants were 24 male and female test participants, military and civilian, who met requirements for binocular vision, 20/20 visual acuity, color and stereo vision. None of the participants were familiar with the test course.

Apparatus

The necessary equipment for this study included

1. One Titmus® II Vision tester device.

2. A high mobility multi-purpose wheeled vehicle (HMMWV), outfitted for teleoperation, with three pairs of stereoscopic viewing cameras and an imagery transmission system. Each stereo pair is outfitted with Panasonic charge coupled device (CCD) cameras and 6-mm (55° FOV) Fujinon lenses.

3. A mock-up of the HMMWV control station with steering wheel, brake and accelerator pedals, and three Sony Trinitron® viewing monitors. The stereoscopic video signals were capable of being shown on all three screens. The test participants viewed the stereo imagery through Toshiba, model VDG3D1 electronically shuttered glasses (see Figure 2).

4. A Sun™ computer and software written to capture time-stamped operator and vehicle behavior data. Collected data consisted of vehicle speed, vehicle revolutions per minute, steering wheel position, brake activity, accelerator position, and vehicle gear. These data were collected at a rate of 20 Hz for possible future manual control modeling efforts.

5. A test course configured at the 13-acre Army Research Laboratory-Aberdeen Test Center (ARL-ATC) outdoor robotics test course which includes sections of pertinent driving scenarios such as straightaway, sharp turns, obstacle avoidance, hills, and slalom. This includes a small figure eight training course (see Figure 3).

Figure 3. ARL-ATC outdoor robotics test course.

6. A demographic data sheet with which to collect all pertinent participant data including pre-screening data. A sample is provided in Appendix A.

7. One self-reporting stress assessment method used to capture the participant's stress levels at different times (specific rating of event [SRE]).

8. The National Aeronautics and Space Administration task load index (NASA TLX), which assesses cognitive workload).

9. A motion sickness questionnaire (MSQ) battery developed by Wiker, Kennedy, McCauley, and Pepper (1979).

10. A questionnaire set, formulated to gather subjective ranked preference data from test participants pertaining to the overall sensory feedback method preferred. (A sample is provided in Appendix A.)

11. A laptop computer with which to collect and store demographic and questionnaire data.

12. Two stopwatches.

PROCEDURE AND METHODOLOGY

As part of the pre-test procedure, participants were given a volunteer affidavit, which described the study and possible risks of motion sickness. There was a possibility that participants would develop such simulator-sickness symptoms as slight eye strain to nausea and dizziness. Participants were fully informed of this possibility.

They were then screened for binocular vision, 20/20 visual acuity, color and stereoscopic vision using a Titmus® II visual testing device. If visual criteria were not met, the participants were excused from the study. Demographic data were collected, and then the test participant was asked to self rate present stress levels by using the SRE scale and to complete a motion sickness assessment questionnaire, as baseline measures.

Before testing, three test course observers, who communicated via walkie-talkies, were positioned at strategic points around the outside of the test course. These observers logged vehicle-obstacle contact. One of the responsibilities of the two far observers was to contact the remaining observer on the platform near the control trailer for emergency stops if necessary.

Training was provided about vehicle operation and safety procedures. Participants drove on a small figure eight test course (see Figure 3). They were trained in the baseline feedback condition (narrow FOV, monoscopic viewing) until the criterion was met. Accuracy was emphasized over the speed of the vehicle. Training was considered complete when the means of the last three training runs for the time performance measured within $\pm 5\%$ of the last three runs' grand mean. When the training criterion was met, the subject was given a briefing about test course features such as barrel placement and navigational cues to use to negotiate the course without experimenter intervention. The experimenter intervened only in the case of a serious course deviation, giving only curt directions to the next navigational cue.

We adhered to ARL safety standing operating procedure (SOP) No. 385-2 supplement No. 01 (Operation of Military and Commercial Telerobotics Systems, September 1990) and a copy was available for reference at the test site. Additionally, we adhered to SOP 335-339, dated 23 Mar 1992 (pertaining to the operation of unmanned ground vehicles), an ATC document.

The study used a 2x2 randomized between-participants design. After being screened, all test participants were randomly assigned to teleoperate in one of four possible experimental conditions: narrow FOV-monoscopic vision, wide FOV-monoscopic vision, narrow FOV-stereoscopic vision, or wide FOV-stereoscopic vision. Each experimental run was limited to only one experimental trial to negate learning effects and to provide an unfamiliar environment.

Test participants were presented one of the four experimental conditions and proceeded with one single run of the actual test course. Accuracy was emphasized over the speed of the vehicle. Following the experimental treatment, each test participant's cognitive workload, stress levels, and motion sickness rating data were collected with the NASA TLX, the SRE (stress), and the motion sickness questionnaire, respectively. Test participants were then shown all four of the possible viewing conditions and were asked to rank order them according to overall preference with a final questionnaire.

Test participants were then fully de-briefed and given a point of contact for pursuit of individual performance or results of the study. Test participants were also informed that any incidents of simulator sickness should be followed by a 1-hour observation period during which the driving of a motor vehicle was strongly discouraged. This was to preclude any potential flashback effects of simulator sickness, which have been known to occur in rare cases.

On-board data were also collected from three practiced HMMWV drivers who were not participants in this study. These on-board data were used for comparison to teleoperated conditions.

RESULTS

The data for the performance measures of task time (time to complete the test course) and error rate (number of obstacles hit and reversals of the vehicle) were analyzed with separate two-way ANOVAs for stereo-mono viewing versus narrow and wide FOV. No significant interaction effects (stereo-mono viewing versus FOV size) were found for any of the dependent variables. Time data were included; however, no significant differences existed for time to complete the test course. The ANOVAs for time data, in seconds, were as shown in Table 2.

Table 2

ANOVAs for Time Data (seconds)

Condition	df	F	P
Field of view x mono-stereo	1,20	.16	.693
Field of view	1,20	1.86	.188
Mono-stereo	1,20	.42	.526

However, a significant main effect for difference in error rate in the stereoscopic-monoscopic viewing conditions was found (F = 5.098, p <.035, df = 1,20). Of the errors committed under the experimental task, the mean number of errors (obstacles contacted) per trial was 6.91 for monoscopic and 4.66 for stereoscopic viewing conditions. The error rate data clearly demonstrate the utility of stereoscopic viewing systems to judge depth in a driving task. Figures 4 and 5 illustrate the mean differences of time and error rate in graphical form. Note that in Figures 4 through 7, on-board data are included for comparison.

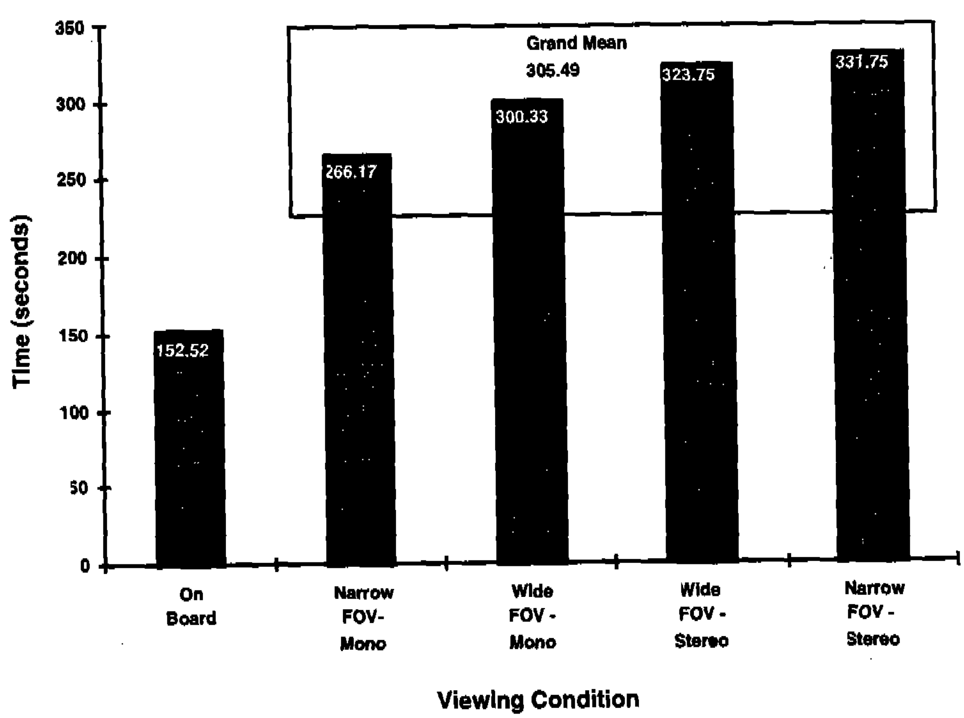

Figure 4. Mean time data comparison.

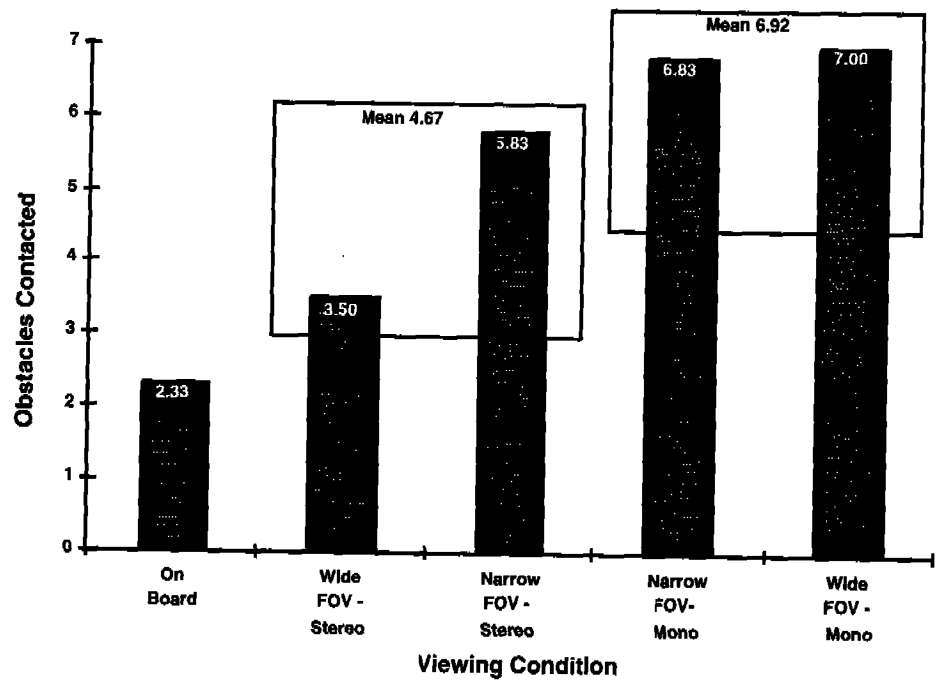

Figure 5. Mean error comparison data for each group.

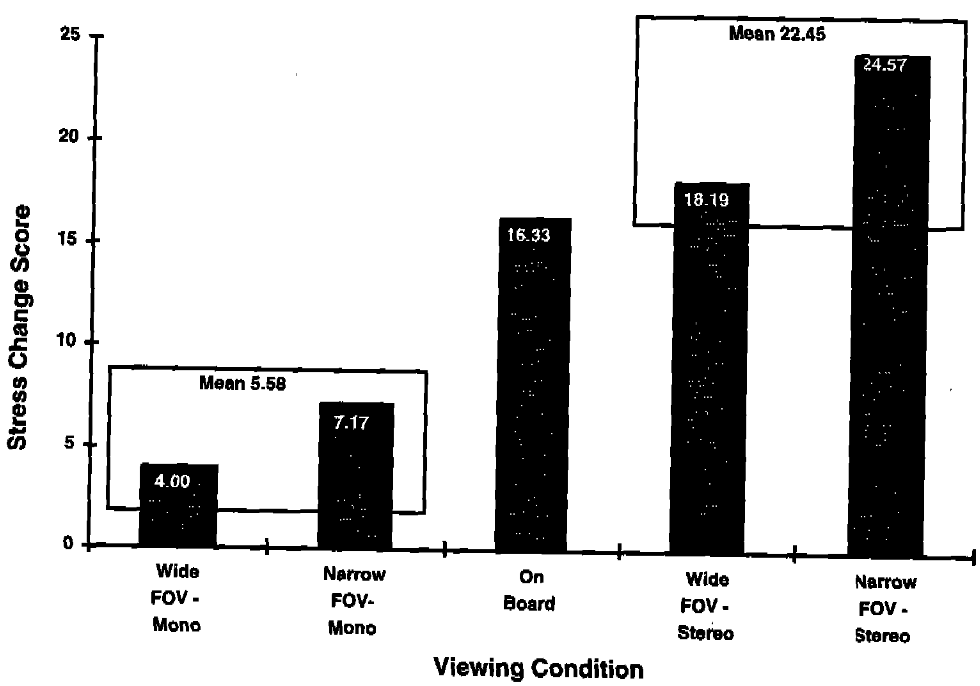

Figure 6. Mean stress change score comparison for each group.

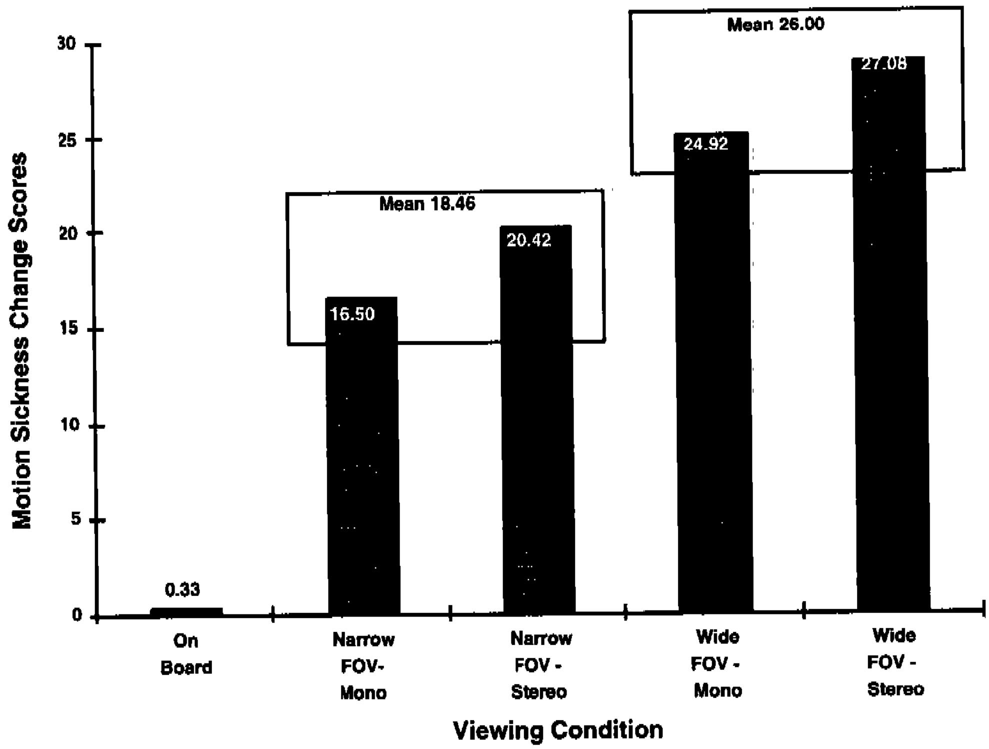

Figure 7. Mean motion sickness rating change score comparison for each group.

The vehicle control measures of steering wheel use, brake use, and accelerator use were analyzed with two-way ANOVAs. No significant results were obtained.

The stress change scores, motion sickness change scores, and overall NASA TLX workload scores were analyzed with two-way ANOVAs. No significant interactions were found, but stress change scores were found to be significant on the stereoscopic-monoscopic viewing dimension ($F = 7.50, p < .012, df = 1,20$). The mean stress change scores were 5.58 and 21.38, for stereoscopic and monoscopic viewing conditions, respectively (see Figure 6). Additionally, a significant difference in motion sickness change scores occurred on the narrow-wide FOV dimension ($F = 10.20, p < .004$). The mean motion sickness change scores were 18.46 and 26.00 for narrow and wide FOV viewing conditions, respectively (see Figure 7).

The teleoperation rank order preference data and viewing dimension deemed most important were analyzed using a chi-square analysis. The rank order preference data yielded a significant difference from expected results ($c = 8.769, p < .0325$). Of 26 observed cases, 12 preferred the wide FOV-stereo condition, 8 preferred the narrow FOV stereo condition, and 3 each preferred the narrow and wide FOV mono conditions (see Figure 8). Data were also collected to determine the single-most important viewing dimension. These data reflected the single aspect of the viewing conditions felt to be most important by the participants. These data also yielded a significant difference from expected results (c = 19.84, p <.0002). Of 26 observed cases, 16 preferred stereoscopic viewing, 4 preferred monoscopic viewing, 5 preferred wide FOV, and 1 preferred narrow FOV (see Figure 9).

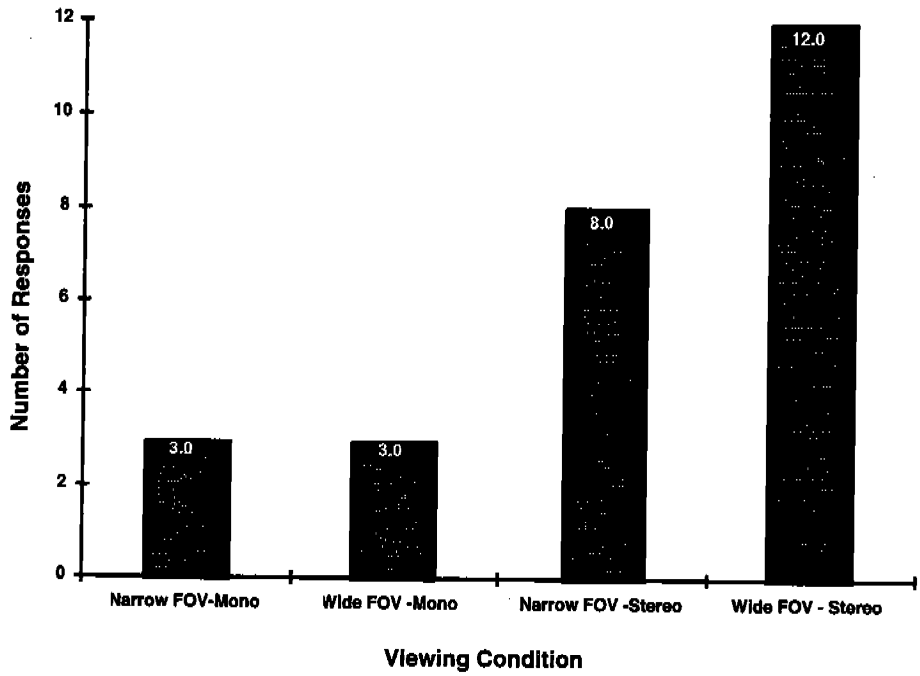

Figure 8. Experimental condition preference.

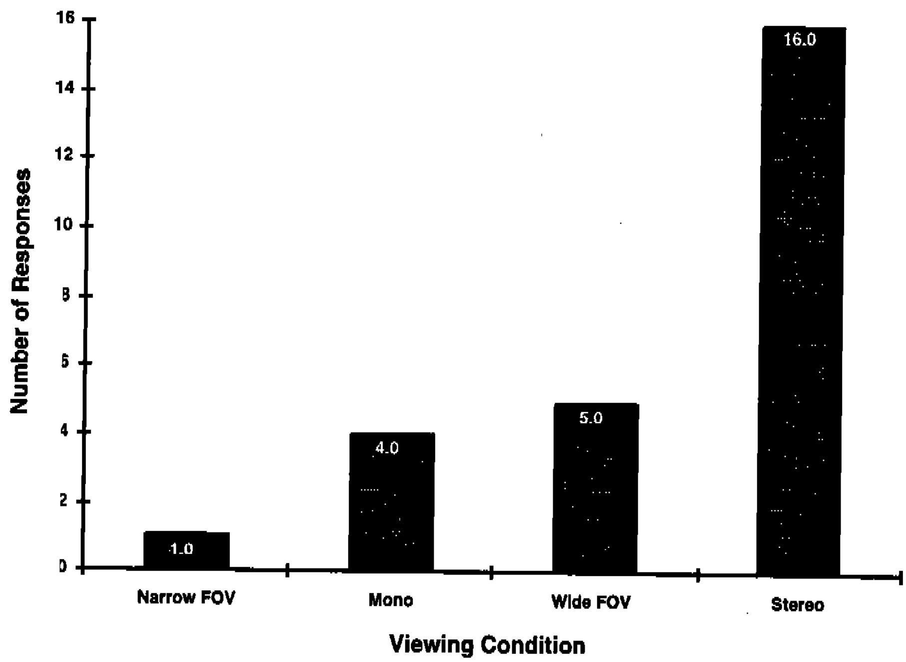

Figure 9. Most important viewing aspect.

An interesting facet of the study is that participants who reported that they were moderately to severely susceptible to motion sickness were those who reported higher rates of motion sickness attributes. Incidentally, two subjects of the entire subject pool failed to complete the test course, after training, because of motion sickness effects (near emesis).

DISCUSSION

A remaining question arises about the contradictory nature of the FOV issue. The literature reports that wide FOV is helpful in those tactical driving tasks that involve turning and terrain navigation in unfamiliar surroundings. The literature also maintains a relationship between wide FOV and simulator sickness, because of the lack of vestibular motion cues in the teleoperators' operating environment.

The FOV was not a significant factor in the results of this study. The data trend in Figure 5, however, demonstrates the real utility or "practical" significance of the combination of stereo vision and wide FOV. The author maintains that if the tactical driving task had been an "open-ended" navigational task using waypoints and terrain recognition as opposed to a path-following driving task, FOV would have proved to be a significant factor in reducing error rate. It is also speculated that FOV would have also contributed to an interaction effect between FOV and depth perception.

It is given that some persons are not susceptible to simulator sickness effects and that some are but are normally "trained" out of being negatively affected through repeated exposure to simulator environments. Should military teleoperator selection criteria include screening for susceptibility to simulator sickness, or should mechanical or medicinal interventions be further investigated to mitigate these effects? Or both? It is offered that the simulator sickness effects of the wide FOV will be "trained out" over time and that a more refined teleoperator screening criterion will reduce the sickness effects and enhance the performance effects of wide FOV.

Future studies involving teleoperated vehicles should involve the use of waypoint navigation over varied and open terrain, which will most likely reveal significant performance differences in the FOV conditions.

CONCLUSIONS

The results of this study demonstrated that there was a difference in the number of obstacles hit between mono and stereo conditions. These differences show the utility of a stereoscopic viewing system to judge depth in the teleoperated driving task. This ability is crucial to future teleoperated Army ground systems in that they must negotiate terrain without suffering moderate to catastrophic damage to the vehicle or a subsystem. Judging depth in the viewing scene substantially aids the driver in traversing around trees, avoiding rocks and other debris, and enables the teleoperator to detect negative obstacles such as holes and ravines, and so forth.

This evidence generally supports the manipulator-related work of Smith et al. (1979), Cole and Parker (1988), Drascic et al. (1989), Drascic (1991), and McLean and Prescott (1991) who demonstrated the advantage of stereo viewing systems for manipulators.

The data also support the findings and suggestions of driving-related research of Kama (1965), Pepper (1983), and McGovern (1987) who generally concluded that stereo provides performance advantages for tasks that require depth positioning, the identification of negative obstacles or involve unfamiliar scenes. The accuracy of depth positioning of the HMMWV, which was driven between pairs of barrels on the test course, relied heavily on the use of stereo vision technology to significantly reduce the number of errors committed.

The drastically divergent stress change scores that were associated with the mono-stereo dimension are thought to be attributed to the increased level of attention and focus associated with stereo driving. The stereo contributed depth perception to the teleoperator's working environment, allowing for more information to be processed, as there were various obstacles to be avoided at nearly a continuous rate throughout the experimental driving task. This increase in information processing demand could easily account for the increased stress levels.

The increased motion sickness change scores associated with the FOV dimension are easily attributable to the wide FOV condition. The results strongly support the Kress and Almaula (1988) findings that relate wide FOV to simulator sickness. Previous literature has reported that the peripheral motion in side views (which are typically added to a center view to increase FOV) in combination with a lack of vestibular (inner ear, semi-circular canals) cues induces simulator sickness effects. This can be induced to a greater or lesser degree, based on the subject's susceptibility to these effects.

The perceived utility of the different experimental conditions as reported by the participants was overwhelmingly in favor of the stereo-wide FOV condition, with stereo-only being a close second place. Additionally, a breakdown of this selection showed that the stereo condition was the element that contributed to this phenomenon. The significant reduction in error rate during the stereo conditions is supported by the significant preferences of that visual display system.

The conclusions from this study can be summarized as follows:

- Error rate was significantly reduced during stereo viewing conditions
- Stress ratings were significantly increased for stereo viewing conditions
- Simulator sickness ratings were significantly increased for wide FOV conditions

RECOMMENDATIONS

In summary, it is recommended that teleoperated systems that use remote control and feedback technologies during conditions when it will be necessary to traverse unfamiliar terrain or surroundings, use stereoscopic imaging systems. It is also recommended, based on trends in the data, that enhanced FOV technologies such as multiple overlapping camera views or head-slaved pan and tilt devices be used on these same systems. The combination of these two technologies will provide the end user the greatest overall benefit for real-time, real-world use. The perception of a wide FOV through the use of a fast-response pan and tilt mechanism would provide essentially the same information as the overlapped camera views at one-third of the bandwidth "cost".

REFERENCES

Chubb, G.P. (1964). A comparison of performance in operating CRL-8 Master-Slave Manipulator under monocular and binocular viewing conditions. (AD 608791) Wright-Patterson Air Force Base, OH: Aerospace Medical Research Laboratories.

Cole, R.E., & Parker, D.L. (1988). Stereo TV improves manipulator performance (Contract Report). Martin-Marietta Aerospace.

Crooks, W.H., Freedman, L.A., & Coan, P.P. (1975). Television systems for remote manipulation. Proceedings of the Human Factors Society 19th Annual Meeting, pp. 423-427.

Drascic, D. (1991). Skill acquisition and task performance in teleoperation using monoscopic and stereoscopic video remote viewing. Proceedings of the Human Factors Society 35th Annual Meeting, p. 1367-71, vol. 2.

Drascic, D, Milgram, P., & Grodski, J. (1989). Learning effects in telemanipulation with monoscopic vs. stereoscopic remote viewing. 1989 IEEE International Conference on Systems, Man and Cybernetics, Conference Proceedings, Cat. No. 89 ch 2809-2, p. 1244-9, vol. 3.

Eveleth, R.G. (1976). Experimental remote control vehicle (RCV) (Report FM-262). Ft. Hood, TX: Headquarters, TCATA.

Gordon, D.A. (1966). Experimental isolation of the driver's visual input. Human Factors, 8, 129-137.

Hudson, E., & Cupit, G. (1968). Stereo TV enhancement study. (Final Technical Report NASA Contract NAS 8-21201). Syosset, NY: Kollsman Instrument Corporation.

Kama, W.N. (1965). Effect of augmented television depth cues on the terminal phase of remote driving (Report AMRL-TR-65-6). Wright-Patterson Air Force Base, OH: Aerospace Medical Research Laboratories.

Kama, W.N., & DuMars, R.C. (1964). Remote viewing: a comparison of direct viewing, 2-D, and 3-D television (Report AMRL-TDR-64-15). Wright-Patterson Air Force Base, OH: 6570th Aerospace Medical Research Laboratories.

Kress, G., & Almaula, H. (December 1988). Sensorimotor requirements for teleoperation (Report R-6279). Santa Clara, CA: FMC Corporate Technology Center.

McGovern, D.E. (1987). Experiences in teleoperation of land vehicles (SAND87-1980, UC-150). Albuquerque, NM: Sandia National Laboratories.

McLean, G.F., & Prescott, B. (1991). Teleoperator task performance using 3-D video. IEEE Pacific Rim Conference on Communications, pp. 615-18, vol. 2.

Merritt, J.O. (1978). Visual information requirements for remotely manned undersea work systems (Contract N66001-78-C-0142). Prepared for Naval Ocean Systems Center, Kailua, HI.

Mitchell, B., Yeager E., Suarez, M., Griffin, J., & Seibert, G. (1994). Cognitive strategies in UGV navigation (Cybernet Systems Corporation, CSC-94-233-2-1). Performed under contract for U.S. Army Research Laboratory, Human Research & Engineering Directorate, Contract No. DAAA-15-93-C-0037.

Mohr, G.C. (1986). Robotic Telepresence. Proceedings of Human Factors Society, 30th Annual meeting, 1986.

Pepper, R.L. (1983). Research issues involved in applying stereoscopic television to remotely operated vehicles. SPIE Proceedings, 402, 170-173, 1983.

Silverman, E.B. (1982). Robotic technology experiments for nuclear power plant inspection and maintenance. Transactions of the American Nuclear Society, 43.

Smith, D.C., Cole, R.E., Merritt, J.O., & Pepper, R.L. (February 1979). Remote operator performance comparing mono and stereo TV displays: The effects of visibility, learning and task factors (NOSC, Technical Report 380). San Diego, CA: Engineering Psychology Programs, Office of Naval Research, Naval Ocean Systems Center.

Spain, E.H. (1987). Assessments of Maneuverability with the teleoperated vehicle (TOV). Paper presented at the 14th Annual Symposium of the Association for Unmanned Vehicle Systems. Washington, DC.

Wheatstone, C. (1838). On Some Remarkable but Hitherto Unobserved Phenomena of Binocular Vision. Phil. Trans. Roy. Soc., 128, (London), pp. 371-394.

Wiker, S.F., Kennedy, R.S., McCauley, M.E., & Pepper, R.L. (May 1979). Reliability, validity, and application of an improved scale of assessment of motion sickness severity (Technical Report No CG-D-29-79). U.S. Department of Transportation.

APPENDIX A

QUESTIONNAIRES

SUBJECT DATA FORM

Please answer the following questions as completely as possible. All information will be coded and kept strictly CONFIDENTIAL.

SUBJECT ID: ____________________ TASK ID: __________________

1. Name________________________ ______________ ____
(last name) (first name) (MI)

Visual Screening Data :

Color Vision [ ] yes [ ] no **Depth Perception** [ ] yes [ ] no **20/20 Vision (corrected)** [ ] yes [ ] no

2. If you are **Military**, please provide the following information:

Rank: _____________________
Military Occupational Specialty (MOS): _________ 2nd MOS: _________
Time in Service: ___________ (years)

3. If you are **Civilian**, please provide the following information:

Job Title: ________________________
Job Series: _______________________
Time in Service: ____________ (years)

4. If you are **neither** Military nor Civilian, please provide the following information:

Job Title: ________________________
Time in Job: ____________ (years)

5. Age: ______

6. Height: _______

7. Weight: ________

8. Handedness (right or left-handed): ____________

9. Do you wear eyeglasses or contact lenses?: _________

10. Do you have a civilian driver's license?: _________ How long?: ______ (years)

11. Do you have a military driver's license?: _________ How long?: ______ (years)

12. If you have a military driver's license, what vehicles are you qualified for?:

Vehicle Type	How Many Years?
____________	__________
____________	__________
____________	__________
____________	__________

13. Have you ever done any high performance competetive driving (i.e. drag racing, stock car racing, etc.)?: ____________

If yes, please describe:______________________________
____
____
____

14. How often do you play video or arcade games? (check one)

Very Frequently	[ ]
Frequently	[ ]
Sometimes	[ ]
Rarely	[ ]
Never	[ ]

15. How well do you perform at video games? (check one)

Exceptional	[ ]
Better than Moderate	[ ]
Moderate	[ ]
Less than Moderate	[ ]
Poorly	[ ]

16. Have you ever operated a vehicle remotely (including radio controlled cars, planes, boats, etc.)?:

____

If yes, please describe:______________________________
____
____
____

17. Have you ever been motion sick (seasick, carsick, airsick, etc)?:________

If yes, please describe:______________________________
____
____
____

18. How susceptible are you to motion sickness? (check one)

Extremely	[ ]
Very	[ ]
Moderately	[ ]
Minimally	[ ]
Not at All	[ ]

VISION TEST	PASS/FAIL													
1. Binocular Vision:	4 Cubes				2 Cubes				3 Cubes					
2. Acuity - Both Eyes	1	2	3	4	5	6	7	8	9	10	11	12	13	14
3. Stereo Depth	1	2	3	4	5	6	7	8	9					
4. Color	A	B	C	D	E	F								
5. Peripheral Vision	55	70	85											

Experimental Condition Rank-Order Form

SUBJECT ID: ___________ TASK ID: ____________

Out of the four experimental conditions, two of which you were exposed to in the experiment, and two of which you were shown after the experiment, how would you rank the order of preference?

where 1 = least desireable
2 = little more desireable
3 = moderately desireable
4 = most desireable

_____ Narrow Field of View - Monoscopic Viewing

_____ Wide Field of View - Monoscopic Viewing

_____ Narrow Field of View - Stereoscopic Viewing

_____ Wide Field of View - Stereoscopic Viewing

Out of four possible single viewing conditions, how would you rank the order of preference?

where 1 = least desireable
2 = little more desireable
3 = moderately desireable
4 = most desireable

_____ Narrow Field of View

_____ Wide Field of View

_____ Monoscopic Viewing

_____ Stereoscopic Viewing

NO. OF COPIES	ORGANIZATION
2	ADMINISTRATOR DEFENSE TECHNICAL INFO CENTER ATTN DTIC DDA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CS AL TA REC MGMT 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CI LL TECH LIB 2800 POWDER MILL RD ADELPHI MD 207830-1197
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CS AL TP TECH PUB BR 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTORATE FOR MANPRINT ATTN DAPE MR DEPUTY CHIEF OF STAFF PERSONNEL 300 ARMY PENTAGON WASHINGTON DC 20310-0300
1	DIRECTOR ARMY AUDIOLOGY & SPEECH CENTER WALTER REED ARMY MED CENTER WASHINGTON DC 20307-5001
1	OUSD(A)/DDDR&E(R&A)/E&LS PENTAGON ROOM 3D129 WASHINGTON DC 20301-3080
1	CODE 1142PS OFFICE OF NAVAL RESEARCH 800 N QUINCY STREET ARLINGTON VA 22217-5000
1	DR ARTHUR RUBIN NATL INST OF STANDARDS & TECH BUILDING 226 ROOM A313 GAITHERSBURG MD 20899
1	COMMANDER US ARMY RESEARCH INSTITUTE ATTN PERI ZT (DR E M JOHNSON) 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333-5600

NO. OF COPIES	ORGANIZATION
1	DEFENSE LOGISTICS STUDIES INFORMATION EXCHANGE ATTN DIRECTOR DLSIE ATSZ DL BLDG 12500 2401 QUARTERS ROAD FORT LEE VA 23801-1705
1	DEPUTY COMMANDING GENERAL ATTN EXS (Q) MARINE CORPS RD&A COMMAND QUANTICO VA 22134
1	HEADQUARTERS USATRADOC ATTN ATCD SP FORT MONROE VA 23651
1	COMMANDER USATRADOC COMMAND SAFETY OFFICE ATTN ATOS (MR PESSAGNO/MR LYNE) FORT MONROE VA 23651-5000
1	COMMANDER US ARMY MATERIEL COMMAND ATTN AMCAM 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333-0001
1	COMMANDER USA OPERATIONAL TEST & EVAL AGENCY ATTN CSTE TSM 4501 FORD AVE ALEXANDRIA VA 22302-1458
1	USA BIOMEDICAL R&D LABORATORY ATTN LIBRARY FORT DETRICK BUILDING 568 FREDERICK MD 21702-5010
1	HQ USAMRDC ATTN SGRD PLC FORT DETRICK MD 21701
1	COMMANDER USA AEROMEDICAL RESEARCH LAB ATTN LIBRARY FORT RUCKER AL 36362-5292
1	US ARMY SAFETY CENTER ATTN CSSC SE FORT RUCKER AL 36362

NO. OF COPIES	ORGANIZATION
1	CHIEF ARMY RESEARCH INSTITUTE AVIATION R&D ACTIVITY ATTN PERI IR FORT RUCKER AL 36362-5354
1	AAMRL/HE WRIGHT PATTERSON AFB OH 45433-6573
1	US ARMY NATICK RD&E CENTER ATTN STRNC YBA NATICK MA 01760-5020
1	US ARMY TROOP SUPPORT CMD NATICK RD&E CENTER ATTN BEHAVIORAL SCI DIV SSD NATICK MA 01760-5020
1	US ARMY TROOP SUPPORT CMD NATICK RD&E CENTER ATTN TECH LIBRARY (STRNC MIL) NATICK MA 01760-5040
1	DR RICHARD JOHNSON HEALTH & PERFORMANCE DIVISION US ARIEM NATICK MA 01760-5007
1	DR JON FALLESEN ARI FIELD UNIT PO BOX 3407 FORT LEAVENWORTH KS 66027-0347
1	COMMANDER USAMC LOGISTICS SUPPORT ACTIVITY ATTN AMXLS AE REDSTONE ARSENAL AL 35898-7466
1	ARI FIELD UNIT FORT KNOX BUILDING 2423 PERI IK FORT KNOX KY 40121-5620
1	STRICOM 12350 RESEARCH PARKWAY ORLANDO FL 32826-3276
1	COMMANDER USA TANK-AUTOMOTIVE R&D CENTER ATTN AMSTA RS/D REES WARREN MI 48090

NO. OF COPIES	ORGANIZATION
1	COMMANDER USA TANK-AUTOMOTIVE R&D CENTER ATTN AMSTA TSL (TECH LIBRARY) WARREN MI 48397-5000
1	INSTITUTE FOR DEFENSE ANALYSES ATTN DR JESSE ORLANSKY 1801 N BEAUREGARD STREET ALEXANDRIA VA 22311
1	GOVT PUBLICATIONS LIBRARY 409 WILSON M UNIVERSITY OF MINNESOTA MINNEAPOLIS MN 55455
1	DR ROBERT KENNEDY ESSEX CORPORATION SUITE 227 1040 WOODCOCK ROAD ORLANDO FL 32803
1	LAWRENCE C PERLMUTER PHD UNIV OF HEALTH SCIENCES THE CHICAGO MEDICAL SCHOOL DEPT OF PSYCHOLOGY 3333 GREEN BAY ROAD NORTH CHICAGO IL 60064
1	DR ARTHUR S KAMLET BELL LABORATORIES 6200 EAST BROAD STREET COLUMBUS OH 43213
1	GENERAL MOTORS CORPORATION NORTH AMERICAN OPERATIONS PORTFOLIO ENGINEERING CENTER HUMAN FACTORS ENGINEERING ATTN MR A J ARNOLD STAFF PROJ ENG ENGINEERING BLDG 30200 MOUND RD BOX 9010 WARREN MI 48090-9010
1	GENERAL DYNAMICS LAND SYSTEMS DIV LIBRARY PO BOX 1901 WARREN MI 48090
1	DR LLOYD A AVANT DEPARTMENT OF PSYCHOLOGY IOWA STATE UNIVERSITY AMES IA 50010
1	DR PAUL R MCCRIGHT INDUSTRIAL ENGINEERING DEPT KANSAS STATE UNIVERSITY MANHATTA KS 66502

NO. OF COPIES	ORGANIZATION
1	DR MM AYOUB DIRECTOR INST FOR ERGONOMICS RESEARCH TEXAS TECH UNIVERSITY LUBBOCK TX 79409
1	MR WALT TRUSZKOWSKI CODE 522.3 NASA/GODDARD SPACE FLIGHT CENTER GREENBELT MD 20771
1	COMMANDER US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE NATICK MA 01760-5007
1	DR DANIEL J POND BATTELLE PNL/K6-66 PO BOX 999 RICHLAND WA 99350
1	HQDA (DAPE ZXO) ATTN DR FISCHL WASHINGTON DC 20310-0300
1	HUMAN FACTORS ENG PROGRAM DEPT OF BIOMEDICAL ENGINEERING COLLEGE OF ENGINEERING & COMPUTER SCIENCE WRIGHT STATE UNIVERSITY DAYTON OH 45435
1	COMMANDER USA MEDICAL R&D COMMAND ATTN SGRD PLC (LTC K FRIEDL) FORT DETRICK MD 21701-5012
1	PEO ARMORED SYS MODERNIZATION US ARMY TANK-AUTOMOTIVE CMD ATTN SFAE ASM S WARREN MI 48397-5000
1	GENERAL ELECTRIC COMPANY ARMAMENT SYSTEMS DEPT RM 1309 ATTN HF/MANPRINT R C MCLANE LAKESIDE AVENUE BURLINGTON VT 05401-4985
1	COMMANDER US ARMY MATERIEL COMMAND ATTN AMCDE AQ 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333

NO. OF COPIES	ORGANIZATION
1	COMMANDANT US ARMY ARMOR SCHOOL ATTN ATSB CDS (MR LIPSCOMB) FT KNOX KY 40121-5215
1	COMMANDER US ARMY AVIATION CENTER ATTN ATZQ CDM S (MR MCCRACKEN) FT RUCKER AL 36362-5163
1	COMMANDER US ARMY SIGNAL CTR & FT GORDON ATTN ATZH CDM FT GORDON GA 30905-5090
1	DIRECTOR US ARMY AEROFLIGHT DYNAMICS DIR MAIL STOP 239-9 NASA AMES RESEARCH CENTER MOFFETT FIELD CA 94035-1000
1	COMMANDER MARINE CORPS SYSTEMS COMMAND ATTN CBGT QUANTICO VA 22134-5080
1	DIRECTOR AMC-FIELD ASSIST IN SCIENCE & TECHNOLOGY ATTN AMC-FAST (RICHARD FRANSEEN) FT BELVOIR VA 22060-5606
1	COMMANDER US ARMY FORCES COMMAND ATTN FCDJ SA BLDG 600 AMC FAST SCIENCE ADVISER FT MCPHERSON GA 30330-6000
1	COMMANDER I CORPS AND FORT LEWIS AMC FAST SCIENCE ADVISER ATTN AFZH CSS FORT LEWIS WA 98433-5000
1	HQ III CORPS & FORT HOOD OFFICE OF THE SCIENCE ADVISER ATTN AFZF CS SA FORT HOOD TX 76544-5056
1	COMMANDER U.S. ARMY NATL TRAINING CENTER AMC FAST SCIENCE ADVISER ATTN AMXLA SA FORT IRWIN CA 92310

NO. OF COPIES	ORGANIZATION
1	COMMANDER HQ XVIII ABN CORPS & FORT BRAGG OFFICE OF THE SCI ADV BLDG 1-1621 ATTN AFZA GD FAST FORT BRAGG NC 28307-5000
1	SOUTHCOM WASHINGTON FIELD OFC 1919 SOUTH EADS ST SUITE L09 AMC FAST SCIENCE ADVISER ARLINGTON VA 22202
1	HQ US SPECIAL OPERATIONS CMD AMC FAST SCIENCE ADVISER ATTN SOSD MACDILL AIR FORCE BASE TAMPA FL 33608-0442
1	HQ US ARMY EUROPE AND 7TH ARMY ATTN AEAGX SA OFFICE OF THE SCIENCE ADVISER APO AE 09014
1	COMMANDER HQ 21ST THEATER ARMY AREA CMD AMC FAST SCIENCE ADVISER ATTN AERSA APO AE 09263
1	COMMANDER HEADQUARTERS USEUCOM AMC FAST SCIENCE ADVISER UNIT 30400 BOX 138 APO AE 09128
1	HQ 7TH ARMY TRAINING COMMAND UNIT #28130 AMC FAST SCIENCE ADVISER ATTN AETT SA APO AE 09114
1	COMMANDER HHC SOUTHERN EUROPEAN TASK FORCE ATTN AESE SA BUILDING 98 AMC FAST SCIENCE ADVISER APO AE 09630
1	COMMANDER US ARMY PACIFIC AMC FAST SCIENCE ADVISER ATTN APSA FT SHAFTER HI 96858-5L00

NO. OF COPIES	ORGANIZATION
1	COMMANDER US ARMY JAPAN/IX CORPS UNIT 45005 ATTN APAJ SA AMC FAST SCIENCE ADVISERS APO AP 96343-0054
1	AMC FAST SCIENCE ADVISERS PCS #303 BOX 45 CS-SO APO AP 96204-0045
1	COMMANDER ALASKAN COMMAND ATTN SCIENCE ADVISOR (MR GRILLS) 6-900 9TH ST STE 110 ELMENDORF AFB ALASKA 99506
1	DR SEHCHANG HAH DEPT OF BEHAVIORAL SCIENCES & LEADERSHIP BUILDING 601 ROOM 281 US MILITARY ACADEMY WEST POINT NEW YORK 10996-1784
1	US ARMY RESEARCH INSTITUTE ATTN PERI IK (DOROTHY L FINLEY) 2423 MORANDE STREET FORT KNOX KY 40121-5620
1	DENNIS SCHMIDT HQDA DAMO FDQ 400 ARMY PENTAGON WASHINGTON DC 20310-0460
1	US MILITARY ACADEMY MATHEMATICAL SCIENCES CENTER OF EXCELLENCE DEPT OF MATHEMATICAL SCIENCES ATTN MDN A MAJ DON ENGEN THAYER HALL WEST POINT NY 10996-1786
1	CECOM SP & TERRESTRIAL COM DIV ATTN AMSEL RD ST MC M H SOICHER FT MONMOUTH NJ 07703-5203
1	PRIN DPTY FOR TECH GY HDQ US ARMY MATL CMND ATTN AMCDCG T M FISETTE 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001

NO. OF COPIES	ORGANIZATION
1	DPTY CG FOR RDE HDQ US ARMY MATL CMND ATTN AMCRD BG BEAUCHAMP 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	DPTY ASST SCY FOR RSRCH & TECH SARD-TT F MILTON RM 3EA79 THE PENTAGON WASHINGTON DC 20310-0103
1	OSD OUSD(A&T)/ODDDR&E(R) J LUPO THE PENTAGON WASHINGTON DC 20301-7100
1	CECOM PM GPS COL S YOUNG FT MONMOUTH NJ 07703
3	DARPA L STOTTS J PENNELLA B KASPAR 3701 N FAIRFAX DR ARLINGTON VA 22203-1714
1	ARL HRED AVNC FIELD ELEMENT ATTN AMSRL HR MJ (R ARMSTRONG) PO BOX 620716 BLDG 514 FT RUCKER AL 36362-0716
1	ARL HRED MICOM FIELD ELEMENT ATTN AMSRL HR MO (T COOK) BUILDING 5400 ROOM C242 REDSTONE ARSENAL AL 35898-7290
1	ARL HRED USAADASCH FLD ELEMENT ATTN AMSRL HR ME (K REYNOLDS) ATTN ATSA CD 5800 CARTER ROAD FORT BLISS TX 79916-3802
1	ARL HRED ARDEC FIELD ELEMENT ATTN AMSRL HR MG (R SPINE) BUILDING 333 PICATINNY ARSENAL NJ 07806-5000
1	ARL HRED ARMC FIELD ELEMENT ATTN AMSRL HR MH (J JOHNSON) BLDG 1109B 3RD FLOOR FT KNOX KY 40121-5215

NO. OF COPIES	ORGANIZATION
1	ARL HRED CECOM FIELD ELEMENT ATTN AMSRL HR ML (J MARTIN) MYER CENTER RM 3C214 FT MONMOUTH NJ 07703-5630
1	ARL HRED FT BELVOIR FIELD ELEMENT ATTN AMSRL HR MK (P SCHOOL) 10115 GRIDLEY ROAD SUITE 114 FORT BELVOIR VA 22060-5846
1	ARL HRED FT HOOD FIELD ELEMENT ATTN AMSRL HR MV (E SMOOTZ) HQ TEXCOM BLDG 91012 RM 111 FT HOOD TX 76544-5065
2	ARL HRED NATICK FIELD ELEMENT ATTN AMSRL HR MQ (M FLETCHER) ATTN SSCNC A (D SEARS) USASSCOM NRDEC BLDG 3 RM R-140 NATICK MA 01760-5015
1	ARL HRED FT HUACHUCA FLD ELEMENT ATTN AMSRL HR MY (B KNAPP) GREELY HALL (BLDG 61801 RM 2631) FORT HUACHUCA AZ 85613-5000
1	ARL HRED FT LEAVENWORTH FLD ELE ATTN AMSRL HR MP (D UNGVARSKY) TPIO ABCS 415 SHERMAN AVE RM 327 FT LEAVENWORTH KS 66027-1344
1	ARL HRED FLW FIELD ELEMENT ATTN AMSRL HR MZ (A DAVISON) 320 ENGINEER LOOP STE 166 FT LEONARD WOOD MO 65473-8929
1	ARL HRED OPTEC FIELD ELEMENT ATTN AMSRL HR MR (D HEADLEY) PARK CENTER IV RM 1450 4501 FORD AVENUE ALEXANDRIA VA 22302-1458
1	ARL HRED SC&FG FIELD ELEMENT ATTN AMSRL HR MS (L BUCKALEW) SIGNAL TOWERS RM 207 FORT GORDON GA 30905-5233
1	ARL HRED STRICOM FIELD ELEMENT ATTN AMSRL HR MT (A GALBAVY) 12350 RESEARCH PARKWAY ORLANDO FL 32826-3276

NO. OF COPIES	ORGANIZATION
1	ARL HRED TACOM FIELD ELEMENT ATTN AMSRL HR MU (M SINGAPORE) BLDG 200A 2ND FLOOR WARREN MI 48397-5000
1	ARL HRED USAFAS FIELD ELEMENT ATTN AMSRL HR MF (L PIERCE) BLDG 3040 RM 220 FORT SILL OK 73503-5600
1	ARL HRED USAIC FIELD ELEMENT ATTN AMSRL HR MW (E REDDEN) BLDG 4 ROOM 332 FT BENNING GA 31905-5400
1	ARL HRED USASOC FIELD ELEMENT ATTN AMSRL HR MN (F MALKIN) HQ USASOC BLDG E2929 FORT BRAGG NC 28307-5000
1	US ARMY RSCH DEV STDZN GP-UK ATTN DR MICHAEL H STRUB PSC 802 BOX 15 FPO AE 09499-1500
	ABERDEEN PROVING GROUND
2	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CI LP (TECH LIB) BLDG 305 APG AA
1	LIBRARY ARL BLDG 459 APG-AA
1	ARL SLAD ATTN AMSRL BS (DR JT KLOPCIC) BLDG 328 APG-AA
1	USMC LIAISON OFFICE ATTN AMST ML RYAN BUILDING APG-AA
1	USATECOM RYAN BUILDING APG-AA
1	COMMANDER CHEMICAL BIOLOGICAL AND DEFENSE COMMAND ATTN AMSCB CI APG-EA

NO. OF COPIES	ORGANIZATION
1	CDN ARMY LO TO TECOM ATTN AMSTE CL TECOM HQ RYAN BLDG
1	CHIEF ARL HRED ERDEC FIELD ELEMENT ATTN AMSRL HR MM (R MCMAHON) BLDG 459 APG-AA

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1998	Final

4. TITLE AND SUBTITLE

The Effect of Stereoscopic and Wide Field of View Conditions on Teleoperator Performance

5. FUNDING NUMBERS

AMS Code: 622716.H700011
PR: 1L162716AH70
PE: 6.27.16

6. AUTHOR(S)

Scribner, D. R.; Gombash, J.W. (both of ARL)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARL-TR-1598

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A study was performed to examine the effects of stereovision and wide field of view (FOV) and their possible interaction with teleoperator performance. The study used a 2x2 (narrow versus wide FOV and mono versus stereo vision) randomized between-subjects design. There were 24 subjects in all, 6 per cell, in conditions of monoscopic-narrow FOV, monoscopic-wide FOV, stereoscopic-narrow FOV, and stereoscopic-wide FOV. No significant interaction effects were found for time or error rate measures. However, analyses of variance (ANOVAs) yielded significant differences between mono and stereo vision for error rate (number of obstacles contacted) as well as reported motion sickness symptoms on the FOV dimension. Self-reported stress levels from pre- to post-run also yielded significant differences on the mono-stereo dimension. Chi-square analyses were performed on questionnaire data for condition preferences. A first chi-square analysis revealed significant findings of first choice of viewing condition, which was stereoscopic-wide FOV. Additionally, a second chi-square analysis of unique viewing conditions showed a significant effect of stereovision; it was the single most preferred viewing condition of all four.

14. SUBJECT TERMS

field of view	stereovision	UGVs
robotics	teleoperator	unmanned vehicle

15. NUMBER OF PAGES

42

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102